

FORM PTO-1390 (REV 11-2000)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER 1340-5
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5) 09/869557 Unknown
INTERNATIONAL APPLICATION NO. PCT/AB99/01135	INTERNATIONAL FILING DATE 21 December 1999	PRIORITY DATE CLAIMED 21 December 1998

TITLE OF INVENTION

NOISE REDUCTION APPARATUS

APPLICANT(S) FOR DO/EO/US

PAN et al.

06-21-2001

U.S. Patent & TMO/TM Mail Rpt Dt. #26

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The U.S. has been elected by the expiration of 19 months from the priority date (Article 31).
5. A copy of the International Application as filed (35 U.S.C. 371(c)(2)).
 - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
 - b. ☒ has been communicated by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
 - a. ☐ is attached hereto.
 - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
 - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ have been communicated by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has **NOT** expired.
 - d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 To 20 below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 C.F.R. 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
14. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821-1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☐ Other items or information.

RECEIVED
JUN 29 2001
ONE/JC/3

U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.53) 09/839537 Unknown		INTERNATIONAL APPLICATION NO. PCT/AU99/01135		ATTORNEY'S DOCKET NUMBER 1340-5				
21. <input checked="" type="checkbox"/> The following fees are submitted:				CALCULATIONS PTO USE ONLY				
BASIC NATIONAL FEE (37 C.F.R. 1.492(a)(1)-(5): -- Neither international preliminary examination fee (37 C.F.R. 1.482) nor international search fee (37 C.F.R. 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO\$1000.00 -- International preliminary examination fee (37 C.F.R. 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO\$860.00 -- International preliminary examination fee (37 C.F.R. 1.482) not paid to USPTO but international search fee (37 C.F.R. 1.445(a)(2)) paid to USPTO\$710.00 -- International preliminary examination fee (37 C.F.R. 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4)\$690.00 -- International preliminary examination fee (37 C.F.R. 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4)\$100.00 <div style="text-align: right;">ENTER APPROPRIATE BASIC FEE AMOUNT =</div>				<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td style="width:10%; text-align: right;">\$</td> <td style="width:60%; text-align: right;">1000.00</td> <td style="width:30%;"></td> </tr> </table>		\$	1000.00	
\$	1000.00							
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input checked="" type="checkbox"/> 30 months from the earliest claimed priority date (37 C.F.R. 1.492(e)).				<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td style="width:10%; text-align: right;">\$</td> <td style="width:60%; text-align: right;">130.00</td> <td style="width:30%;"></td> </tr> </table>		\$	130.00	
\$	130.00							
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE					
Total Claims	24	-20 = 4	X \$18.00	\$	72.00			
Independent Claims	2	-3 = 0	X \$80.00	\$	0.00			
MULTIPLE DEPENDENT CLAIMS(S) (if applicable)			\$270.00	\$	0.00			
TOTAL OF ABOVE CALCULATIONS =				\$	1202.00			
<input checked="" type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				\$	0.00			
SUBTOTAL =				\$	1202.00			
Processing fee of \$130.00, for furnishing the English Translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 C.F.R. 1.492(f)).				\$	0.00			
TOTAL NATIONAL FEE =				\$	1202.00			
Fee for recording the enclosed assignment (37 C.F.R. 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 C.F.R. 3.28, 3.31). \$40.00 per property				\$	0.00			
Fee for Petition to Revive Unintentionally Abandoned Application (\$1240.00 - Small Entity = \$620.00)				\$	0.00			
TOTAL FEES ENCLOSED =				\$	1202.00			
				Amount to be:				
				refunded	\$			
				Charged	\$			

☒ A check in the amount of \$1202.00 to cover the above fees is enclosed.

☐ Please charge my Deposit Account No. 14-1140 in the amount of \$_____ to cover the above fees. A duplicate copy of this form is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 14-1140. A duplicate copy of this form is enclosed.

d. ☒ The entire content of the foreign application(s), referred to in this application is/are hereby incorporated by reference in this application.

NOTE: Where an appropriate time limit under 37 C.F.R. 1.494 or 1.495 has not been met, a petition to revive (37 C.F.R. 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

NIXON & VANDERHYE P.C.
1100 North Glebe Road, 8th Floor
Arlington, Virginia 22201-4714
Telephone: (703) 816-4000

SIGNATURE

Arthur R. Crawford
NAME

25,327
REGISTRATION NUMBER

June 21, 2001
Date

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of

PAN et al.

Atty. Ref.: 1340-5

Serial No. Unknown

Group:

Filed: June 21, 2001

Examiner:

For: NOISE REDUCTION APPARATUS

* * * * *

June 21, 2001

Assistant Commissioner for Patents
Washington, DC 20231

Sir:

PRELIMINARY AMENDMENT

In order to place the above-identified application in better condition for examination,
please amend the application as follows:

IN THE CLAIMS

Please substitute the following amended claims for corresponding claims previously
presented. A copy of the amended claims showing current revisions is attached.

3. (Amended) A noise reduction apparatus as claimed in claim 1, further comprising
reference sensor means and reference signal conditioning means responsive to the reference
sensor means to produce the reference signal therefrom.
4. (Amended) A noise reduction apparatus as claimed in claim 1, wherein the error sensor
means is provided adjacent to an operator's head in use.

6. (Amended) A noise reduction apparatus as claimed in claim 1, wherein the apparatus further comprises a plurality of transducers and the control means comprises a plurality of controllers each of which is associated with one of the transducers, each controllers producing a control signal for the associated transducer.
8. (Amended) A noise reduction apparatus as claimed in claim 6, wherein at least one said controllers comprises a feedback control channel.
10. (Amended) A noise reduction apparatus as claimed in claim 6, wherein the transducers comprise audio transducers and/or vibration transducers.
11. (Amended) A noise reduction apparatus as claimed in claim 1, further comprising monitoring means arranged to monitor the noise level in the enclosure and disable the control means if the noise exceeds a predetermined threshold.
15. (Amended) A noise reduction apparatus as claimed in claim 13, further comprising reference sensor means and reference signal conditioning means responsive to the reference sensor means to produce the reference signal therefrom.
16. (Amended) A noise reduction apparatus as claimed in claim 13, wherein the error sensor means is provided adjacent to an operator's head in use.
18. (Amended) A noise reduction apparatus as claimed in claim 13, wherein the apparatus further comprises a plurality of transducers and the control means comprises a plurality of channels each of which is associated with one of the transducers, each channel producing a control signal for the associated transducer.
20. (Amended) A noise reduction apparatus as claimed in claim 18, wherein at least one channel of the control means comprises a feedback control channel.

PAN et al.
Serial No. **Unknown**

22. (Amended) A noise reduction apparatus as claimed in claim 18, wherein the transducers comprise audio transducers and/or vibration transducers.

23. (Amended) A noise reduction apparatus as claimed in claim 13, further comprising monitoring means arranged to monitor the noise level in the enclosure and disable the control means if the noise exceeds a predetermined threshold.

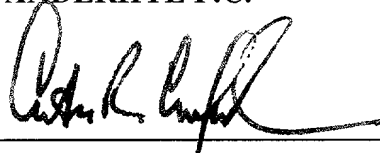
REMARKS

The above amendments are made to place the claims in a more traditional format. Attached hereto is a marked-up version of the changes made to the claims by the current amendment. The attached page is captioned "**Version With Markings To Show Changes Made.**"

Respectfully submitted,

NIXON & VANDERHYE P.C.

By: _____



Arthur R. Crawford
Reg. No. 25,327

ARC:ms
1100 North Glebe Road, 8th Floor
Arlington, VA 22201-4714
Telephone: (703) 816-4000
Facsimile: (703) 816-4100

VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE CLAIMS

3. (Amended) A noise reduction apparatus as claimed in claim 1 [or 2], further comprising reference sensor means and reference signal conditioning means responsive to the reference sensor means to produce the reference signal therefrom.

4. (Amended) A noise reduction apparatus as claimed in [any one of the preceding claims] claim 1, wherein the error sensor means is provided adjacent to an operator's head in use.

6. (Amended) A noise reduction apparatus as claimed in [any one of the preceding claims] claim 1, wherein the apparatus further comprises a plurality of transducers and the control means comprises a plurality of controllers each of which is associated with one of the transducers, each controllers producing a control signal for the associated transducer.

8. (Amended) A noise reduction apparatus as claimed in claim 6 [or 7], wherein at least one said controllers comprises a feedback control channel.

10. (Amended) A noise reduction apparatus as claimed in [any one of claims 6 to 9] claim 6, wherein the transducers comprise audio transducers and/or vibration transducers.

11. (Amended) A noise reduction apparatus as claimed in [any one of the preceding claims] claim 1, further comprising monitoring means arranged to monitor the noise level in the enclosure and disable the control means if the noise exceeds a predetermined threshold.

15. (Amended) A noise reduction apparatus as claimed in claim 13 [or 14], further comprising reference sensor means and reference signal conditioning means responsive to the reference sensor means to produce the reference signal therefrom.

16. (Amended) A noise reduction apparatus as claimed in [any one claims 13 to 15] claim 13, wherein the error sensor means is provided adjacent to an operator's head in use.

18. (Amended) A noise reduction apparatus as claimed in [any one claims 13 to 17] claim 13, wherein the apparatus further comprises a plurality of transducers and the control means comprises a plurality of channels each of which is associated with one of the transducers, each channel producing a control signal for the associated transducer.

20. (Amended) A noise reduction apparatus as claimed in claim 18 [or 19], wherein at least one channel of the control means comprises a feedback control channel.

22. (Amended) A noise reduction apparatus as claimed in [any one of claims 18 to 21] claim 18, wherein the transducers comprise audio transducers and/or vibration transducers.

23. (Amended) A noise reduction apparatus as claimed in [any one claims 13 to 22] claim 13, further comprising monitoring means arranged to monitor the noise level in the enclosure and disable the control means if the noise exceeds a predetermined threshold.

TITLE

"Noise Reduction Apparatus"

FIELD OF THE INVENTION

This invention relates to a noise reduction apparatus. The invention has
5 particular, although not exclusive, utility in relation to use in cabins of heavy
mining vehicles, where low frequency noise can present an occupational hazard.
The invention can also be used in areas where noise is considered undesirable,
such as marine vessels.

BACKGROUND ART

- 10 Most prior noise reduction systems for cabins have employed a feed-forward
control system using a filtered-x least mean square (LMS) algorithm. One such
system is disclosed in US patent specification 5,245,664. Whilst providing an
adaptive controller, the conventional filtered-x LMS controller is known to have a
slow convergence rate. As a result, control systems making use of the filtered-x
15 LMS algorithm can perform poorly when the noise changes abruptly, such as
when the vehicle changes gear.

This problem has, to some extent, been addressed by using pre-compiled feed-
forward control systems, such as those described in US patent specifications
4,506,380, 5,692,052 and 5,758,311. Such control systems do not suffer from
20 slow convergence, however the pre-compiled nature of the controller limits the
adaptability of the controller.

Accordingly, there exists a need for an adaptive controller having a reasonable
convergence rate.

In addition, field trials of noise cancellation systems have shown that operators of
25 heavy mining equipment have individual preferences regarding the level of noise
attenuation at certain frequencies. Some drivers use the sound of the engine as

part of their sensory input in controlling the vehicle. Accordingly, it would be desirable to provide a noise reduction system in which the level of attenuation can be adjusted or at least selected from a plurality of predefined configurations.

DISCLOSURE OF THE INVENTION

- 5 Throughout the specification, unless the context requires otherwise, the word "comprise" or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

- 10 In accordance with a first aspect of this invention, there is provided a noise reduction apparatus for an enclosure, comprising:

error sensor means arranged to generate an error signal;

control means responsive to a reference signal to produce a control signal;

a transducer responsive to the control signal;

the control means comprising:

- 15 a first controller responsive to the reference signal to produce the control signal for the transducer,

a plant model responsive to the reference signal to produce a signal input to a second controller,

- 20 signal generation means for producing a further error signal from the output of the second controller, the output of the first controller and the error signal, and

adaptive means responsive to the further error signal to adjust the parameters of the first and second controllers simultaneously.

Preferably, the apparatus further comprises shaping filter means provided between the signal generation means and the adaptive means and arranged to process the further error signal and produce a processed further error signal input to the adaptive means.

- 5 Preferably, the apparatus further comprises reference sensor means and reference signal conditioning means responsive to the reference sensor means to produce the reference signal therefrom.

Preferably, the error sensor means is provided adjacent to an operator's head in use.

- 10 Preferably, the error sensor means comprises two microphones, one provided adjacent each ear of the operator.

Preferably, the apparatus further comprises a plurality of transducers and the control means comprises a plurality of controllers each of which is associated with one of the transducers, each controllers producing a control signal for the
15 associated transducer.

Preferably, at least one of said controllers comprises a feedforward control channel.

Preferably, at least one said controllers comprises a feedback control channel.

- 20 Preferably, the reference signal for each feedback controller comprises a further signal produced by the signal generation means.

Preferably, the transducers comprise audio transducers and/or vibration transducers.

- 25 Preferably, the apparatus further comprises monitoring means arranged to monitor the noise level in the enclosure and disable the control means if the noise exceeds a predetermined threshold.

Preferably, said monitoring means resets the parameters of the controllers prior to enabling the control means.

In accordance with a second aspect of this invention, there is provided a noise reduction apparatus for an enclosure, comprising:

- 5 error sensor means arranged to generate an error signal;
- control means responsive to a reference signal to produce a control signal;
- a transducer responsive to the control signal;
- the control means comprising:
- 10 a first controller responsive to the reference signal to produce the control signal for the transducer,
- shaping filter means responsive to a user's selection, provided between the signal generation means and the adaptive means and arranged to process the error signal and produce a processed further error signal input to the adaptive means,
- 15 adaptive means responsive to the processed error signal to adjust the parameters of the first controller.

Preferably, said control means further comprises a plant model responsive to the reference signal to produce a signal input to a second controller, signal generation means provided before the shaping filter means for producing a further error

20 signal from the output of the second controller, the output of the first controller and the error signal, the further error signal being input to the shaping filter means.

Preferably, the apparatus further comprises reference sensor means and reference signal conditioning means responsive to the reference sensor means to produce the reference signal therefrom.

Preferably, the error sensor means is provided adjacent to an operator's head in use.

Preferably, the error sensor means comprises two microphones, one provided adjacent each ear of the operator.

- 5 Preferably, the apparatus further comprises a plurality of transducers and the control means comprises a plurality of channels each of which is associated with one of the transducers, each channel producing a control signal for the associated transducer.

- 10 Preferably, at least one channel of the control means comprises a feedforward control channel.

Preferably, at least one channel of the control means comprises a feedback control channel.

Preferably, the reference signal for each feedback control channel comprises a further signal produced by the signal generation means.

- 15 Preferably, the transducers comprise audio transducers and/or vibration transducers.

Preferably, the apparatus further comprises monitoring means arranged to monitor the noise level in the enclosure and disable the control means if the noise exceeds a predetermined threshold.

- 20 Preferably, said monitoring means resets the parameters of the first and second controller prior to enabling the control means.

BRIEF DESCRIPTION OF THE DRAWINGS

- 25 Figures 1a and 1b are side and front views, respectively, of a vehicle cabin incorporating the noise reduction apparatus according to the preferred embodiment of the invention;

Figure 2 is a block diagram of a feedforward control circuit of the embodiment;

Figure 3 is a block diagram of a feedback control circuit of the embodiment; and

Figure 4 is a block diagram of a reference signal conditioning circuit of the embodiment.

5 BEST MODE(S) FOR CARRYING OUT THE INVENTION

The embodiment relates to a noise reduction apparatus denoted generally at 10 provided in a cabin 12 of a heavy mining vehicle or a marine vessel. However, it should be appreciated that the invention can be applied to control noise in other forms of enclosures, and that such enclosures need not be fully enclosed.

- 10 The noise in the cabin 12 of such a vehicle is often the product of several noise sources, such as the engine, the exhaust/muffler system and auxiliary equipment such as hydraulics, compressors, air conditioning units and fans, as well as noise sources external to the vehicle. Each of these noise sources can produce noise in the cabin 12 either by transmission of sound into the cabin 12, or by causing
- 15 vibrations in the structure of the cabin 12, which in turn creates noise within the cabin 12. The embodiment uses a controller having a two channel feedforward circuit and a single channel feedback circuit.

In the embodiment, the cabin 12 includes a floor panel 14, a seat 16 attached to the floor 14 and a ceiling panel 18.

- 20 The noise reduction apparatus 10 of the embodiment comprises two reference sensors 20a and 20b, three error sensors 22a, 22b and 22c, a controller 24 and three transducers 26a, 26b and 26c.

The reference sensor 20a comprises a vibration sensor and is provided adjacent the vehicle's engine 28. The reference sensor 20b comprises a microphone

25 provided near the vehicle's muffler 30.

The error sensors 22a and 22b each comprise a microphone provided above the seat 16. The error sensors 22a and 22b are provided spaced apart at opposite sides of the seat 16 such that in use, the operator's head would be received between the error sensors 22a and 22b. The error sensors 22a and 22b are
5 connected to the controller 24.

The error sensor 22c comprises a vibration sensor that is provided on the floor panel 14 of the cabin 12. The error sensor 22c is connected to the controller 24.

In the embodiment, the controller 24 comprises a 2 channel feedforward circuit 24a, a single channel feedback circuit 24b and a reference signal conditioning
10 circuit 24c. The reference signal conditioning circuit 24c forms a reference signal from information received from the reference sensors 20a and 20b.

The error sensors 22a and 22b each provide an error signal to one channel of the feedforward circuit 24a of the controller 24. The error sensor 22c provides an error signal to the feedback control circuit 24b.

15 The transducers 26a and 26b comprise audio transducers such as loud speaker drivers. The transducers 26a and 26b are attached to the ceiling panel 18 of the cabin 12 and are positioned generally above the corresponding error sensor 22a and 22b, respectively. In other embodiments, the transducers may be provided at other locations, depending upon the installation requirements and the available
20 space in the cabin or other enclosure.

The transducer 26c comprises a vibration transducer attached to the floor panel 14. The error sensor 22c and the transducer 26c are provided on opposite sides of the floor panel 14 so as to be co-located one above the other. The transducer 26c may be in the form of a piezoelectric transducer or a magnetostrictive
25 actuator. It is preferred that if used, the piezoelectric transducer is placed at a node of vibrations in the floor panel 14, whilst a magnetostrictive actuator is provided at an antinode of vibrations in the floor panel 14. Again, on other embodiments, vibrational transducers may be provided in other locations depending on installation requirements.

Each of the transducers 26a, 26b and 26c are connected to the controller 24 and receive control signals therefrom. The transducers 26a and 26b each receive a control signal from one channel of the feedforward control circuit 24a, and the transducer 26c receives a control signal from the feedback control circuit 24b.

- 5 Figure 2 shows a block diagram of the feedforward control circuit 24a. The feedforward control circuit 24a is responsive to a reference signal 32 produced by the reference signal conditioning circuit 24c, described below, from the signals received from the reference sensors 20a and 20b. The purpose of the reference signal conditioning circuit 24c is to increase the correlation between the reference
10 signal 32 and the noise (shown in figure 3 at 34) in the cabin 12, improve the signal to noise ratio and adjust the relative balance between the signals received from the reference sensors 20a and 20b.

- A plant 36 is shown in figure 2, representing the electro-acoustic system corresponding to the transducers 26a and 26b and the acoustic path between
15 said transducers and the region about the user's head, where noise reduction is desired.

The feedforward control circuit 24a includes a first control system 38, an adaptive LMS system 40 and a shaping filter 42.

- The first control system 38 receives the reference signal 32 and, based on its
20 current parameters, produces a control signal shown at 44. The control signal 44 is sent to the transducer which forms part of the plant 36. In the embodiment, two feedforward control circuits 24a are used to produce two control signals 44, one for each of the transducers 26a and 26b. Each of the feedforward control circuits 24a use the same reference signal 32 produced by the reference signal
25 conditioning circuit 24c.

The error signal, shown at 46, produced by each of the error sensors 22a and 22b is the sum of the noise 34 and the response of the plant 36 to the control signal 44. In the embodiment, the error sensor 22a produces an error signal for one of the channels of the feedforward control circuit 24a and the error sensor 22b

produces an error signal for the other channel of the feedforward control circuit 24a.

Existing feed-forward controllers would pass the error signal 46 into an adaptive LMS system along with the reference signal 32 so that the adaptive LMS system
5 can update the parameters of the first control system 38. However, this would require the adaptive LMS system to be a filtered-x LMS system, which has a slow convergence.

To avoid this problem, the feedforward control circuit 24a includes a plant model 48, a second control system 50 and a signal generating means 52. The reference
10 signal 32 is input to the plant model 48, and the output of the plant model 48 is input to the second control system 50 and the adaptive LMS system 40. The output of the second control system 50 is input to the signal generating means 52. The error signal 46 is also input to the signal generating means 52. The signal generating means 52 includes a further plant model 48 which takes as an input
15 the control signal 44. The output of the further plant model 48 is subtracted from the error signal 46 to arrive at a model of the noise 34 shown at 54 in Figure 2. The model of the noise 54 is then combined with the output of the controller 50 to produce a second error signal at 56. Advantageously, the second error signal 56 allows the adaptive LMS system 40 to use traditional LMS convergence rates
20 rather than the slow filtered-x convergence rate.

The second error signal 56 is input to the shaping filter 42. The shaping filter 42 forms a filtered error signal which is input to the adaptive LMS system 40. The adaptive LMS system 40 then makes adjustments to the operational parameters of the first and second control systems 38 and 50 in order to minimise the filtered
25 error signal input to the adaptive LMS system 40. The same changes are made to the parameters of both the control systems 38 and 50, such that the first and second controllers 38 and 50 have the same parameters.

The shaping filter 42 modifies the second error signal 56 prior to input to the adaptive LMS system 40. This provides two advantages. First, a user can
30 customise the noise reduction achieved at certain frequency ranges according to

his or her preferences. Since the adaptive LMS system 40 attempts to minimise the signal appearing at its input from the output of the shaping filter 42, any portions of the second error signal 56 that are filtered or attenuated by the shaping filter 42 will not be attenuated to a significant degree by the controller 24.

- 5 Depending upon the implementation adopted, the shaping filter 42 can offer customisable shaping or provide a plurality of predetermined shaping filters from which a user can select one. Secondly, the shaping filter 42 can be used to adjust the sensitivity of the controller 24 at certain frequency ranges. Since the gain-bandwidth product of a control system is finite, reducing the bandwidth over which
- 10 the controller must work in effect increases the amount of attenuation delivered to the remaining frequencies. This is particularly advantageous if the anticipated noise spectra of the cabin 12 is known. These two effects can be used in combination to allow design-level control of the operating frequency ranges, within which a user can adjust the noise reduction achieved at certain frequency ranges
- 15 according to his or her preferences

Figure 3 shows a block diagram of the feedback control circuit 24b. Like reference numerals are used in relation to figure 3 as were used in figure 2. The feedback control circuit 24b shown in figure 3 differs from that shown in figure 2 in that a model noise signal 54 is used to replace the reference signal 32 by feeding

20 the signal 54 back to the input of the first control system 38 and plant model 48. The feedforward control circuit 24b shown in figure 3 is used to control the transducer 26c.

Although not shown in the drawings, the noise reduction system 10 also includes a monitoring circuit that monitors the control signal 44. If the control signal 44

25 exceeds a predetermined threshold criteria, the controllers 50 and 38 are deactivated by the monitor circuit. This is to prevent noise within the cabin 12 reaching excessive levels if the controller 24 malfunctions and increases rather than decreases the noise within the cabin 12. The monitoring circuit also resets the parameters within the first and second controllers 38 and 50 back to an initial

30 condition, following which the control systems 38 and 50 are enabled.

Figure 4 shows a block diagram of the reference signal conditioning circuit 24c. The reference signal conditioning circuit 24c comprises two bandpass filters 60a and 60b, two phase locked loops (PLLs) 62a and 62b, two phase compensators 64a and 64b, a summer 66 and a buffer 68.

- 5 The bandpass filter 60a, the PLL 62a, and the phase compensator 64a are connected in series, with the bandpass filter 60a being responsive to the signal received from the reference sensor 20a. The output from the phase compensator 64a is connected to an input of the summer 66.

- 10 The bandpass filter 60b, the PLL 62b, and the phase compensator 64b are connected in series, with the bandpass filter 60b being responsive to the signal received from the reference sensor 20b. The output from the phase compensator 64b is connected to another input of the summer 66.

- 15 The bandpass filters 60a and 60b define the selectivity of the controller 24 and are used to remove unwanted frequency components present in the signals from the reference sensors 20a and 20b, respectively.

- 20 The PLLs 62a and 62b lock onto a frequency component of the filtered signals from the bandpass filters 60a and 60b. The PLLs 62a and 62b have a limited frequency band of operation to prevent them from tracking other components in the filtered signals. The bandwidth of operation of the PLLs 62a and 62b is selected based on the expected rate of change of the noise sources. For example, if the engine changes gear over the course of 500ms, a bandwidth of 2Hz is chosen for the PLLs 62a and 62b. Each of PLLs 62a and 62b produce a constant-amplitude output from its voltage controlled oscillator (not shown).

- 25 The output of each PLL 62a, 62b is input to a corresponding phase compensator 64a and 64b. The phase compensators 64a and 64b provide adjustment of the relative phase between the signals output from the PLLs 62a and 62b.

The summer 66 adds the signals received from the phase compensators 64a and 64b. The buffer 68 provides gain trimming for the summed signal. The output of the buffer 68 forms the reference signal 32.

It should be appreciated that this invention is not limited to the particular
5 embodiment described above.

For example, although the embodiment is described as having a two channel feed-forward control circuit and a single channel feedback control circuit, other embodiments may use only one form of control circuit or may utilise any number of channels as needed.

10 It should be noted that the reference sensors can take any appropriate form. In particular, in relation to the engine 28 it may be possible to utilise an indication of the speed of the engine from the tachometer or an audible signal derived from the engine bay rather than a vibration signal.

CLAIMS

1. A noise reduction apparatus for an enclosure, comprising:

error sensor means arranged to generate an error signal;

control means responsive to a reference signal to produce a control
signal;

a transducer responsive to the control signal;

the control means comprising:

a first controller responsive to the reference signal to produce
the control signal for the transducer,

a plant model responsive to the reference signal to produce a
signal input to a second controller,

signal generation means for producing a further error signal
from the output of the second controller, the output of the first
controller and the error signal, and

adaptive means responsive to the further error signal to
adjust the parameters of the first and second controllers
simultaneously.

2. A noise reduction apparatus as claimed in claim 1, further comprising
shaping filter means provided between the signal generation means and
the adaptive means and arranged to process the further error signal and
produce a processed further error signal input to the adaptive means.

3. A noise reduction apparatus as claimed in claim 1 or 2, further comprising
reference sensor means and reference signal conditioning means



responsive to the reference sensor means to produce the reference signal therefrom.

4. A noise reduction apparatus as claimed in any one of the preceding claims, wherein the error sensor means is provided adjacent to an operator's head in use.

5. A noise reduction apparatus as claimed in claim 4, wherein the error sensor means comprises two microphones, one provided adjacent each ear of the operator.

6. A noise reduction apparatus as claimed in any one of the preceding claims, wherein the apparatus further comprises a plurality of transducers and the control means comprises a plurality of controllers each of which is associated with one of the transducers, each controllers producing a control signal for the associated transducer.

7. A noise reduction apparatus as claimed in claim 6, wherein at least one of said controllers comprises a feedforward control channel.

8. A noise reduction apparatus as claimed in claim 6 or 7, wherein at least one said controllers comprises a feedback control channel.

9. A noise reduction apparatus as claimed in claim 8, wherein the reference signal for each feedback controller comprises a further signal produced by the signal generation means.

10. A noise reduction apparatus as claimed in any one of claims 6 to 9, wherein the transducers comprise audio transducers and/or vibration transducers.

11. A noise reduction apparatus as claimed in any one of the preceding claims, further comprising monitoring means arranged to monitor the noise level in

the enclosure and disable the control means if the noise exceeds a predetermined threshold.

12.A noise reduction apparatus as claimed in claim 11, wherein said monitoring means resets the parameters of the controllers prior to enabling the control means.

13.A noise reduction apparatus for an enclosure, comprising:

error sensor means arranged to generate an error signal;

control means responsive to a reference signal to produce a control signal;

a transducer responsive to the control signal;

the control means comprising:

a first controller responsive to the reference signal to produce the control signal for the transducer,

shaping filter means responsive to a user's selection, provided between the signal generation means and the adaptive means and arranged to process the error signal and produce a processed further error signal input to the adaptive means,

adaptive means responsive to the processed error signal to adjust the parameters of the first controller.

14.A noise reduction apparatus as claimed in claim 13, wherein said control means further comprises a plant model responsive to the reference signal to produce a signal input to a second controller, signal generation means provided before the shaping filter means for producing a further error signal from the output of the second controller, the output of the first controller

and the error signal, the further error signal being input to the shaping filter means.

5 15.A noise reduction apparatus as claimed in claim 13 or 14, further comprising reference sensor means and reference signal conditioning means responsive to the reference sensor means to produce the reference signal therefrom.

16.A noise reduction apparatus as claimed in any one claims 13 to 15, wherein the error sensor means is provided adjacent to an operator's head in use.

10 17.A noise reduction apparatus as claimed in claim 16, wherein the error sensor means comprises two microphones, one provided adjacent each ear of the operator.

15 18.A noise reduction apparatus as claimed in any one claims 13 to 17, wherein the apparatus further comprises a plurality of transducers and the control means comprises a plurality of channels each of which is associated with one of the transducers, each channel producing a control signal for the associated transducer.

19.A noise reduction apparatus as claimed in claim 18, wherein at least one channel of the control means comprises a feedforward control channel.

20 20.A noise reduction apparatus as claimed in claim 18 or 19, wherein at least one channel of the control means comprises a feedback control channel.

21.A noise reduction apparatus as claimed in claim 20, wherein the reference signal for each feedback control channel comprises a further signal produced by the signal generation means.



22. A noise reduction apparatus as claimed in any one of claims 18 to 21, wherein the transducers comprise audio transducers and/or vibration transducers.

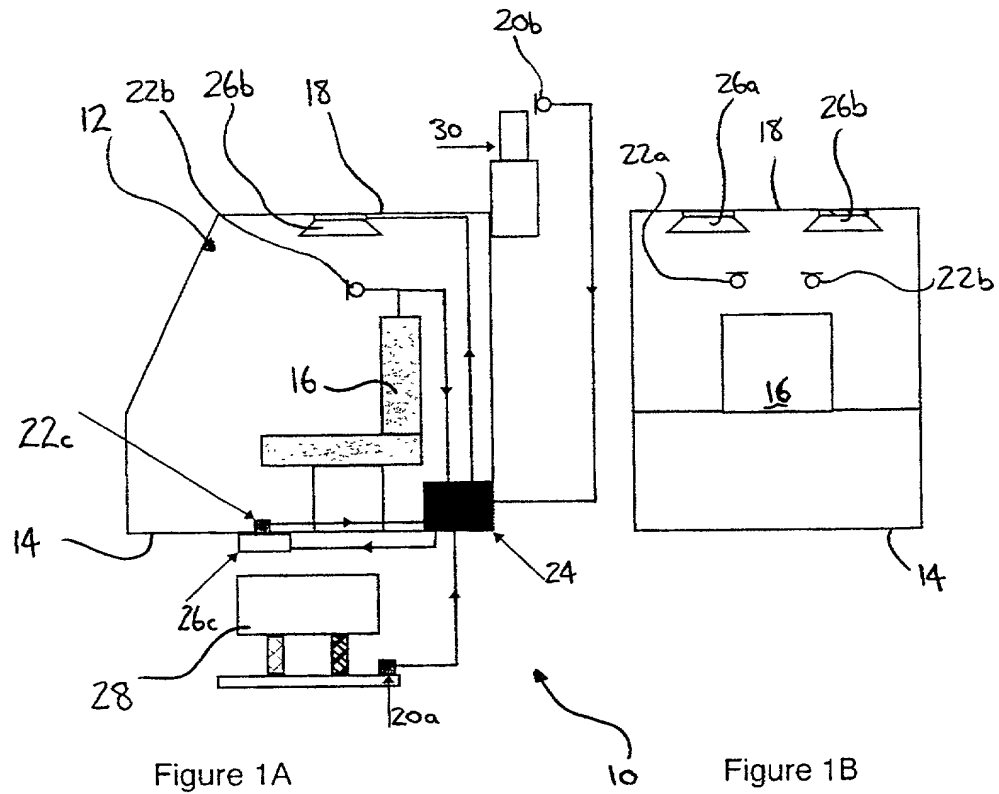
5

23. A noise reduction apparatus as claimed in any one claims 13 to 22, further comprising monitoring means arranged to monitor the noise level in the enclosure and disable the control means if the noise exceeds a predetermined threshold.

10

24. A noise reduction apparatus as claimed in claim 23, wherein said monitoring means resets the parameters of the first and second controller prior to enabling the control means.

11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000



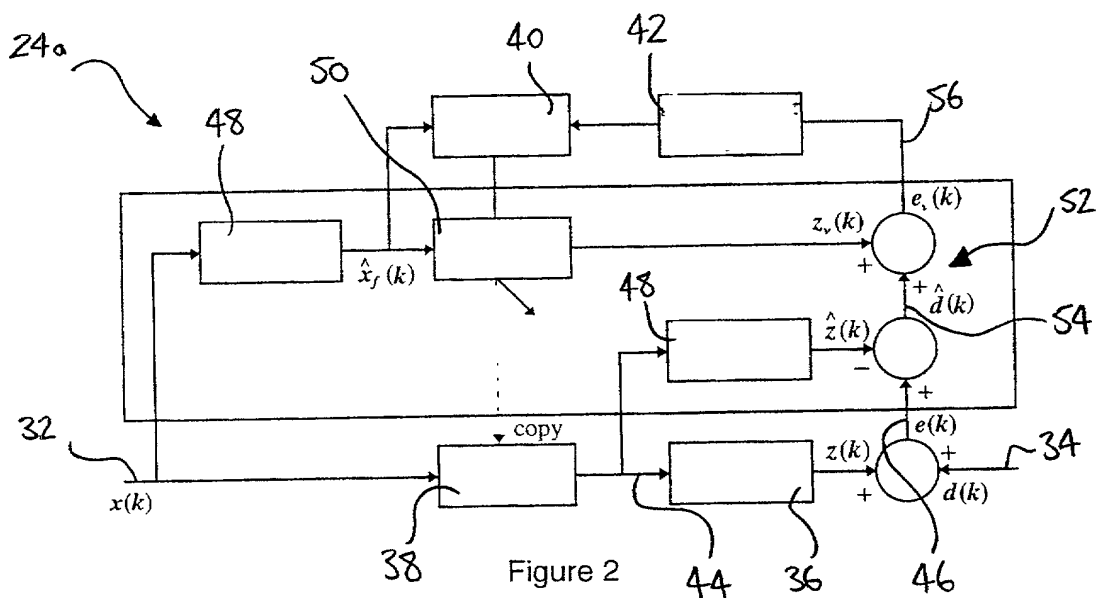


Figure 2

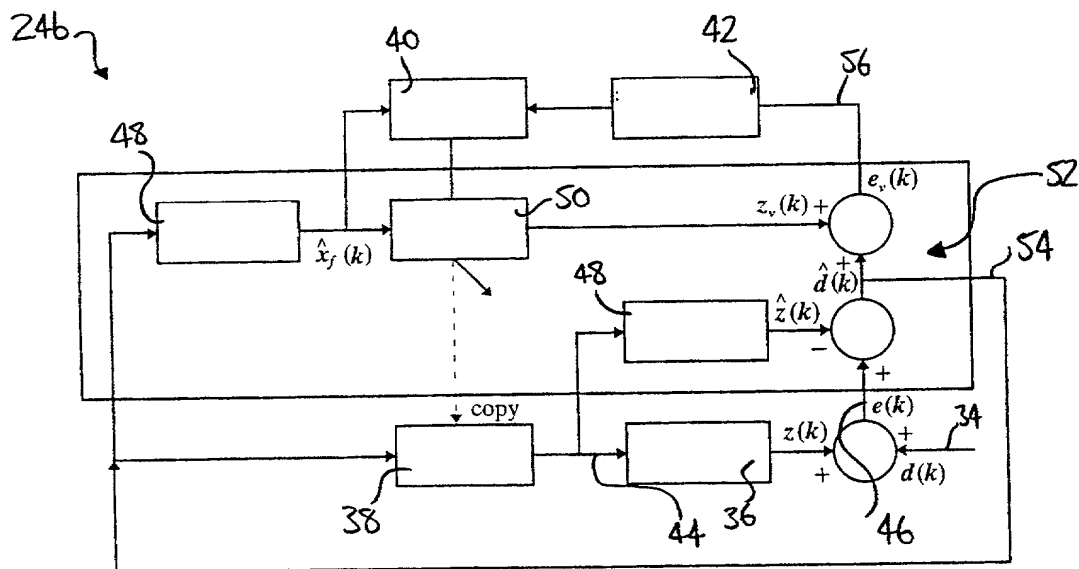


Figure 3

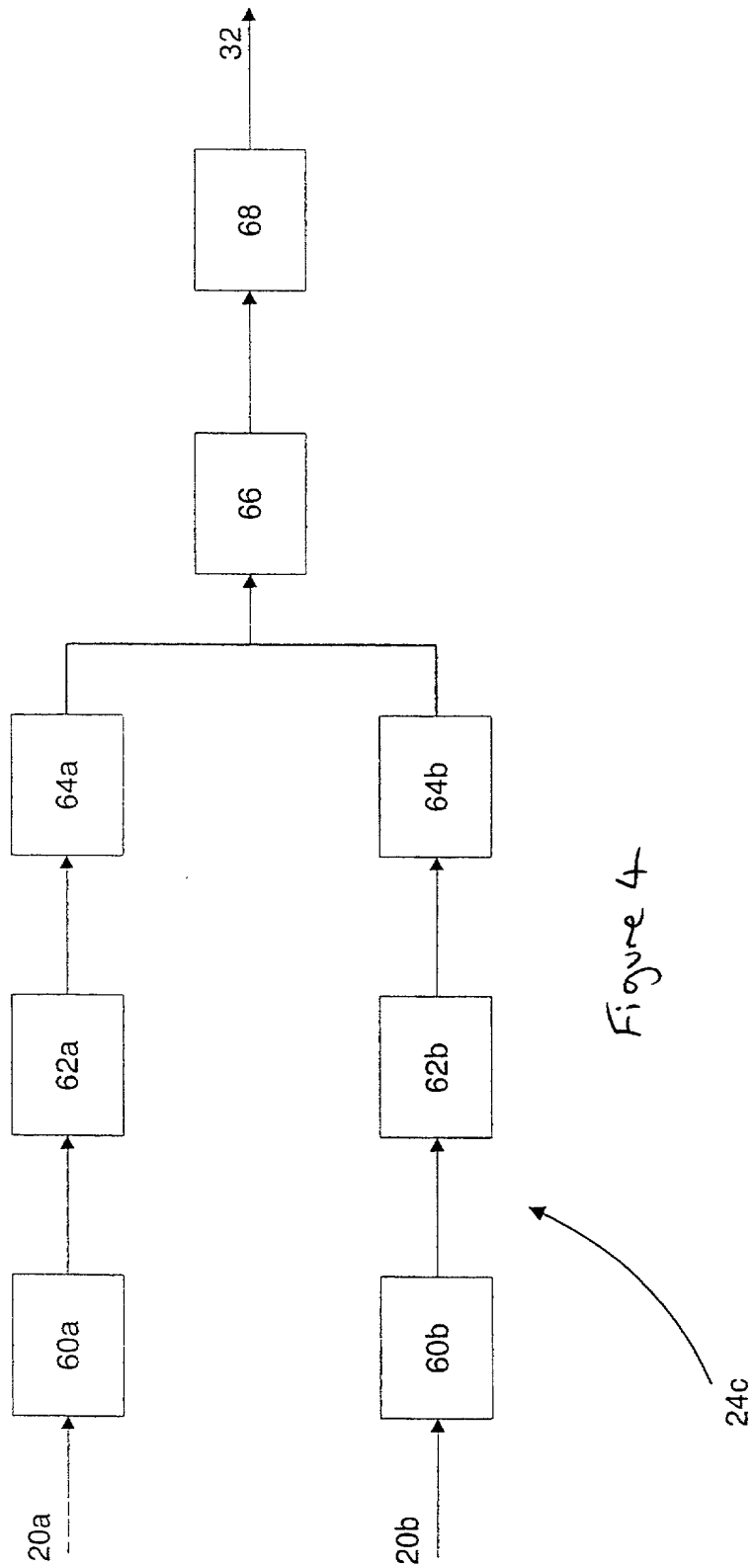


Figure 4

RULE 63 (37 C.F.R. 1.63)
INVENTORS DECLARATION FOR PATENT APPLICATION
IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

As a below named inventor, I hereby declare that my residence, mailing address and citizenship are as stated below next to my name, and I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

NOISE REDUCTION APPARATUS

the specification of which (check applicable box(es)):

☐ is attached hereto
☒ was filed on June 21, 2001 as U.S. Application Serial No. _____ (Atty Dkt. No. 1340-5)
☒ was filed as PCT International application No. PCT/AU99/01135 on 21 December 1999
and (if applicable to U.S. or PCT application) was amended on _____

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose to the Patent Office all information known to me to be material to patentability as defined in 37 C.F.R. 1.56. I hereby claim foreign priority benefits under 35 U.S.C. 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed or, if no priority is claimed, before the filing date of this application:

Priority Foreign Application(s):

Application Number	Country	Day/Month/Year Filed
PP 7826	AUSTRALIA	21 December 1998

I hereby claim the benefit under 35 U.S.C. §119(e) of any United States provisional application(s) listed below:

Application Number	Date/Month/Year Filed
--------------------	-----------------------

I hereby claim the benefit under 35 U.S.C. 120/365 of all prior United States and PCT international applications listed above or below:

Prior U.S./PCT Application(s):

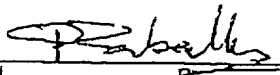
Application Serial No.	Day/Month/Year Filed	Status: patented pending, abandoned
PCT/AU99/01135	21 December 1999	

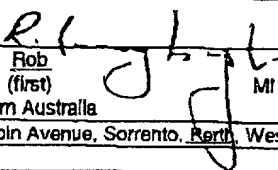
I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon. And on behalf of the owner(s) hereof, I hereby appoint **NIXON & VANDERHYE P.C., 1100 North Glebe Rd., 8th Floor, Arlington, VA 22201-4714, telephone number (703) 816-4000** (to whom all communications are to be directed), and the following attorneys thereof (of the same address) individually and collectively owner's/owners' attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith and with the resulting patent: Larry S. Nixon, 25640; Arthur R. Crawford, 25327; James T. Hesmer, 30184; Robert W. Faris, 31352; Richard G. Besha, 22770; Mark E. Nusbaum, 32348; Michael J. Keenan, 32106; Bryan H. Davidson, 30251; Stanley C. Spooner, 27393; Leonard C. Mitchard, 29009; Duane M. Byers, 33363; Jeffry H. Nelson, 30481; John R. Lastova, 33149; H. Warren Burnam, Jr., 29366; Mary J. Wilson, 32955; J. Scott Davidson, 33489; Alan M. Kagen, 36178; Robert A. Molan, 29834; B. J. Sadoff, 36663; James D. Berquist, 34776; Updeep S. Gill, 37334; Michael J. Shea, 34725; Donald L. Jackson, 41080; Michelle N. Lester, 32331; Frank P. Presta, 19828; Joseph S. Presta, 35329; Joseph A. Rhoads, 37515; Raymond Y. Mah, 41428; Chris Comuntzis, 31087. I also authorize Nixon & Vanderhye to delete any attorney names/numbers no longer with the firm and to act and rely solely on instructions directly communicated from the person, assignee, attorney, firm, or other organization sending instructions to Nixon & Vanderhye on behalf of the owner(s).

1. Inventor's Signature: *Pan Jie* Date: 7-9-2001
Inventor: Jie (first) PAN (last) Australia (citizenship)
Residence: (city) Western Australia (state/country) Australia
Mailing Address: The University of Western Australia, Dept. of Mechanical and Materials Engineering, Stirling Highway, Nedlands, Perth, Western Australia, Australia AU 6907
(Zip Code) 6907

2. Inventor's Signature: *Chao Ying* Date: 7-9-2001
Inventor: Ying (first) CHAOYING (last) Australia (citizenship)
Residence: (city) Western Australia (state/country) Australia
Mailing Address: The University of Western Australia, Dept. of Mechanical and Materials Engineering, Stirling Highway, Nedlands, Perth, Western Australia, Australia AU 6907
(Zip Code) 6907

☒ See attached sheet(s) for additional inventor(s) information!!

3. 00 Inventor's Signature:  Date: 7-09-2001
Inventor: Mohammed PAUROBALLY
(first) (last)
MI (state/country) Australia
Residence: (city) Western Australia
Mailing Address: The University of Western Australia, Dept. of Mechanical and Materials Engineering, Stirling Highway,
Nedlands, Perth, Western Australia, Australia A LIX
(Zip Code) 6907

4. 00 Inventor's Signature:  Date: 7-9-2001
Inventor: Rob GREENHALGH
(first) (last)
MI (state/country) Australia
Residence: (city) Western Australia
Mailing Address: 38 Robin Avenue, Sorrento, Perth, Western Australia, Australia A LIX
(Zip Code) 6020

FOR ADDITIONAL INVENTORS, check box ☐ and attach sheet with same information and signature and date for each.